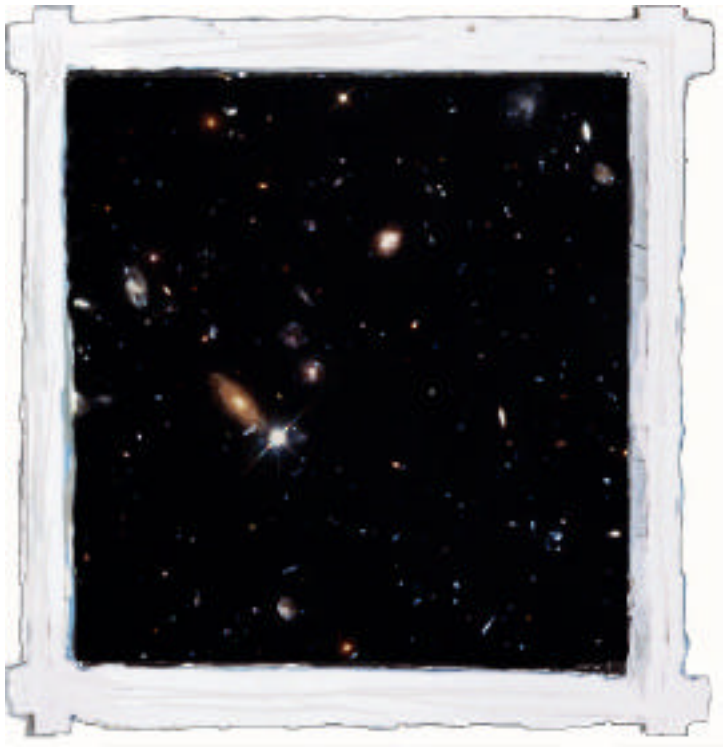
ORIGINS / NGST



The Next Generation Space Telescope

"Visiting a Time When Galaxies Were Young"
-from HST and Beyond, AURA

Technology Roadmaps

James Bilbro
Sandy Montgomery

September 15, 1997

GSFC

NGST Program Organization

NGST

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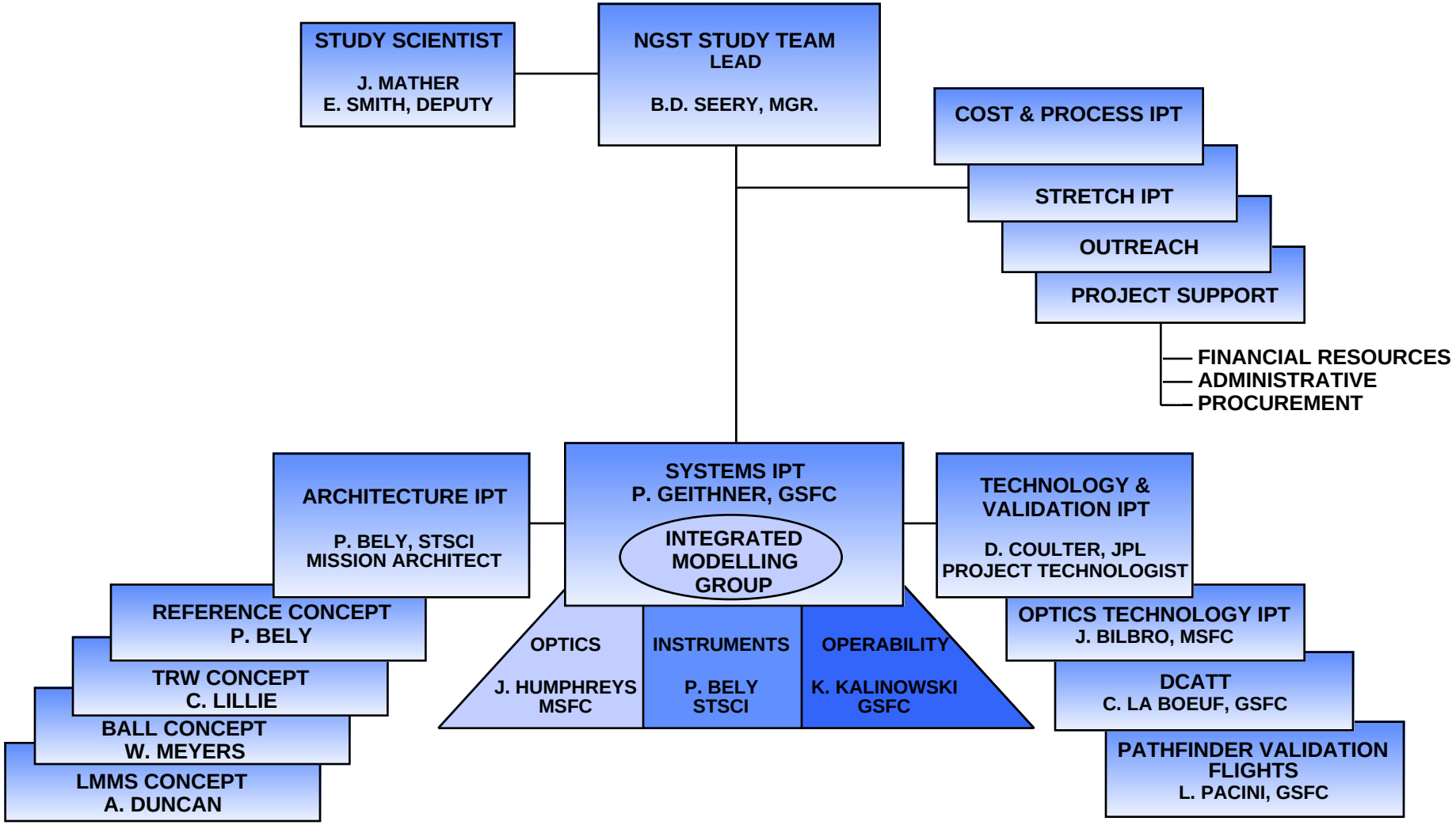

NGST Technology Roadmap
The Road to the Roadmap

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Budget

HST and Beyond (Dressler) Committee Report

NGST Feasibility Study

TRW Team

Lockheed-Martin Team

NASA Team

Integ. Review 8/96

NGST Technology Plan

MSFC NGST Optics Symposium

1st Origins Technology Workshop

Large Aperture Space Telescope SBIR Focused Topic

NGST Technology Roadmap

Phase I SBIRs

NMSD

BASIC | Option 1 | Cryo Test

Arch Studies

Actuator RFO

ISIM RFO

SBeMD

Basic | Option 1

Advanced MSD

Basic&Opt1 | Cryo

Stretch MSD

Basic | Option 1

Technology Roadmap Update

Phase II SBIRs

Phase I SBIRs

Technology Challenge Review July, 1997

Technology Challenge Review July, 1998

Flight Demonstrations - System Testbeds

- embedded electronics
- Profilometry
- optical edge sensor
- polyimide films
- PZT Coatings
- Memory Alloy Coatings
- cryo DM
- waterjet fab
- Composites
- CVD SiC
- RB SiC
- CFR SiC
- SCS
- Graphite
- Hi-Tc Actuators

NGST Technology Prioritization
MSFC IPT Responsibility

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Optical Telescope Assembly
- **Ultralightweight Mirrors**
- **Cryogenic Actuators**
- **Cryogenic Deformable Mirror**
- Deployable Structures
- Wavefront Sensing & Optical Control

MSFC Optics IPT

Science Instrument Module
- **Low Noise NIR Detectors**
- High Q.E. TIR detectors
- Large Format Arrays
- Digital mirror
- Vibrationless Cryo-Coolers

Mission Operations
- **Flight Software Methodologies**
- **Autonomous On-board Schedule Execution**
- Data Compression
- Control Executive
- Autonomous Fault Management
- User Interaction Tools

Spacecraft Support Module
- **Inflatable or Deployable Sunshade**
- **Vibration Isolation**
- Advanced Startracker
- Low Temperature Materials Property Characterization

Systems
- **Integrated Modeling**
- **Mission Simulator**

“TALL TENT POLES” IN BOLD

Ultralightweight Mirror Technology Development Roadmap

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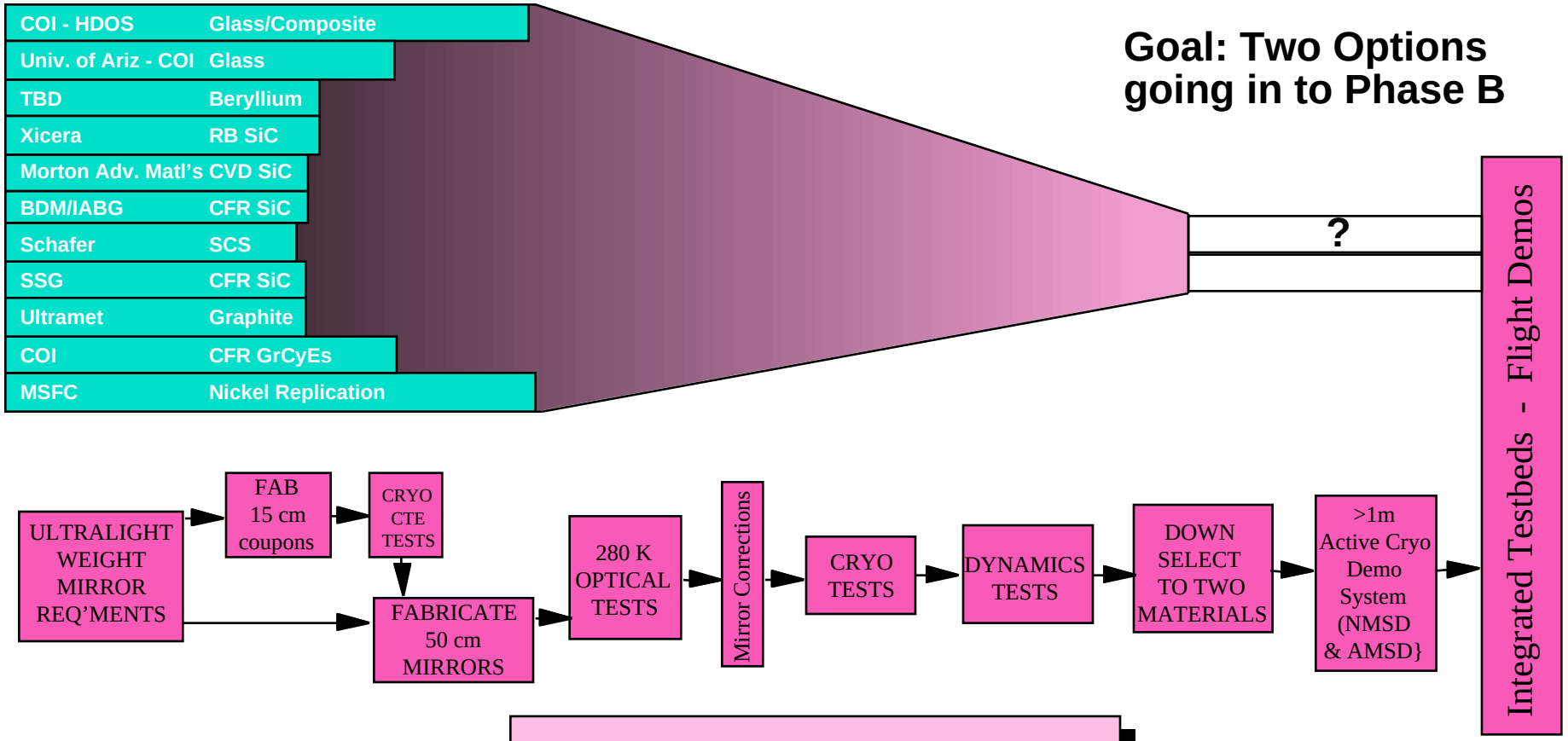

CRITICAL REQUIREMENTS

- **AREAL DENSITY OF 5-10 kg/m^2**
- **DIFFRACTION LIMITED @ 2 μm**
- **OPERATION @ 30K**

Ultralightweight Mirror Systems Relative State of the Art

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		<15 cm	50 cm	>1 m
Univ. of Arizona - COI	Glass			NMSD
COI - HDOS	Glass/Comp.			NMSD
BerylliumTBD	Beryllium		SBeMD	Adv. Mirror Sys. Demo
Xicera	RB SiC	SBIR-I	SBIR-II	
Morton Adv. Matl's	CVD SiC	SS FFP	SS FO	
BDM/IABG	CFR SiC	SS FFP	SS FO	
Schafer	SCS	SS FFP	SS FO	
SSG	CFR SiC	SBIR-I	SBIR-II	
Ultramet	Graphite	SBIR-I	SBIR-II	
COI	CFR GrCyEs	SBIR-I	SBIR-II	
MSFC	ED Ni	CC		

East Coast Optics Technology Survey 9/22-26/97

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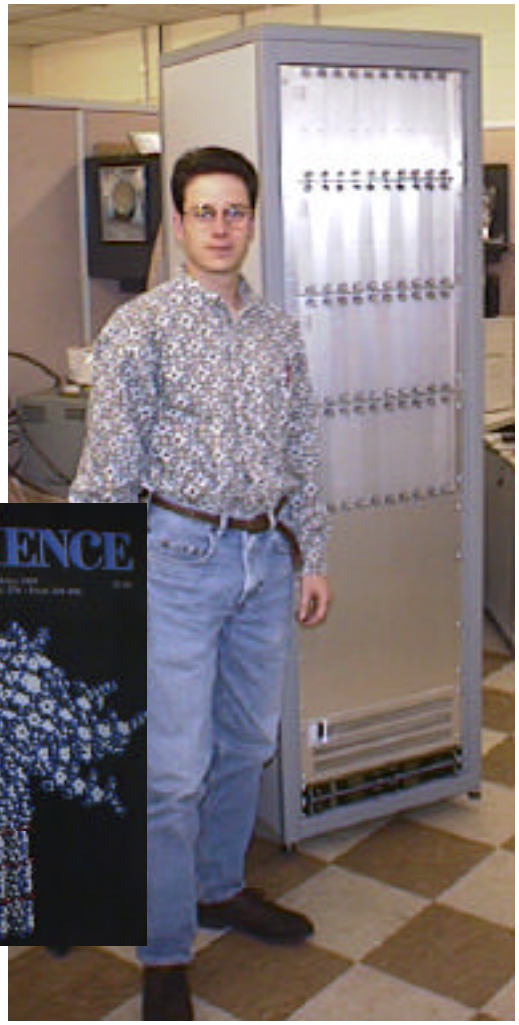
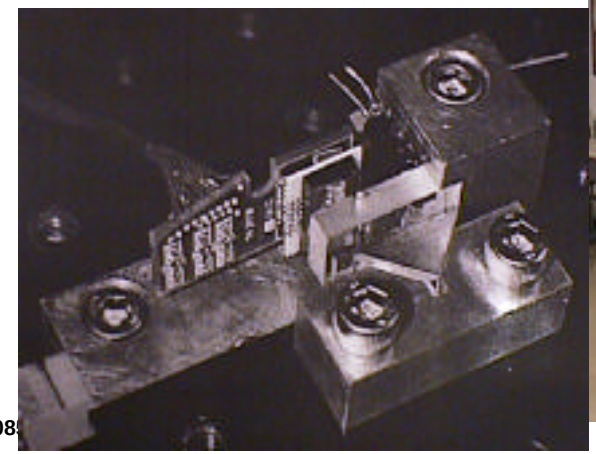
- Visited with a number of **Phase I SBIR** houses to review their technologies
  - Digital Optics, Charlotte SC. - optical edge sensors
  - Arrowhead, Newport News, VA - polyimide electronics substrates
  - Xinetics, Devon, MA - cryo deformable mirror (actuators and electronics)
  - Foster Miller, Waltham, MA - supramolecular structures for PZT thin films
  - Bauer Associates, Wellesley, MA - Large Asphere Mirror Profilometry
  - Advanced Tech Materials, Danbury, CT - PLZT films for high density DRAM

- Also visited **Hughes Danbury** Optical Systems
  - Reviewed past history in Beryllium including SIRTF
  - discussed alternate methods of fabricating large area mirrors

- Visited with **LaRC**
  - Reviewed in-house research on THUNDER piezoelectric actuators.
  - Reviewed SBIR work and in-house research in embedded electronics





East Coast Optics Technology Survey 9/22-26/97

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- NGST Optics leads visited the centers of excellence in **Silicon Carbide** Mirrors on this side of the Atlantic (all in the Boston area):
  - Morton Advance Materials - CVD
  - Xicera - Reaction Bonded
  - SSG - Carbon Fiber Reinforced

- **Topics discussed** included
  - Status of technology
  - Current research to resolve technology issues
  - Mirror size limits due to fabrication processes/facilities
  - Why no bid on NMSD competition (most common answer:>50cm fab not ready)

Mirror Faceplate

XINETICS INC - Littleton, MA - PI:MARK A. EALEY, COTR:Max Nein/MSFC

LARGE, LOW-TEMPERATURE SILICON CARBIDE MIRRORS

- Trade studies complete on optimum mirror stiffness
- Understanding of effects of various % free silicon
- 15 cm mirror produced - λ/10, surface < 20Å
- Phase II Proposal Submitted

SSG INC - WALTHAM, MA - PI: DEXTER WANG, COTR:Ritva Keski-Kuha/GSFC

ULTRA-LIGHTWEIGHT CONTINUOUS FIBER REINFORCED CERAMIC(CFRC) SILICON CARBIDE MIRROR SUBSTRATES FOR NGST

- FEM models show CFRC should meet NGST specs on at least meter scales.
- Fabricated four mirrors:15-22cm dia., flat & spherical, 3.7-9.6 kg/m2, various lightweighting schemes
- various matrix materials, reaction conditions evaluated
- finishing techniques studied
- Phase II Proposal Submitted

ULTRAMET - PACOIMA, CA - PI:Brian WIlliams, COTR:MSFC

ULTRALIGHTWEIGHT, THERMOMECHANICALLY STABLE PYROLYTIC GRAPHITE COMPOSITE MIRRORS

- based on past success with SiC on SiC foam
- Graphite deposited on SiC OK, but on SiC foam too much distortion.
- finishing techniques show residual stress high
- problem in cooling from high deposition temp - time, temp, pressure. Needs further research.
- No Phase II Proposal Submitted - will resubmit Phase I this round.

Fabrication

COMPOSITE OPTICS INC - SAN DIEGO, CA .PI:Randy ClarkCOTR:Eri Cohen/JPL

LIGHTWEIGHT CARBON FILTER COMPOSITE MIRROR FABRICATION USING ADVANCED CORE TECHNOLOGY

- 5 kg/m2 , core geometry to minimize weight
- co-curing glass microsheet bonded onto composite
- trade studies on rib sizes, material selection,
- designed & built half meter without glass - 6” Plano geometries with glass
- Phase II Proposal submitted

COMPOSITE OPTICS INC - SAN DIEGO, CA - PI:Greg Mehle - COTR:Arif Husain /JPL

HIGH PRECISION FABRICATION METHODS NAS8-97203

- Replicate metal on glass slumped over ceramic blocking bodies
- less expensive, reusable, precision, low CTE surface
- 12” diameter demo of 1/2 inch pocket miled flat pyrex into curvature.
- Master made for 28”diameter, 3 radius of curvature tool.
- Phase II Proposal submitted

WATERJET TECH INC- KENT, WA - PI:DIANA J. SUZUKI - COTR:?/MSFC

LIGHTWEIGHTING AND SHAPING OF NGST OPTICS WITH ABRASIVE-WATERJETS

- pocket milling of 13 triangular and square patterns in 0.125-0.25 “ thick pyrex
- innovative technique to prevent undercutting, webs 1/8 inch wall thickness
- anchor nodes for composite structure - .060” deep holes in corners
- nozzle improvements - volumetric removal rates up by factor of two
- simple cost analysis for removing material - $38/lb removed material
- Phase II Proposal submitted

NASA 1996 SBIR PHASE I
LASTS - Ultralightweight Mirrors

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COMPOSITE OPTICS INC - SAN DIEGO, CA - PI? - COTR:Hall/MSFC

EVALUATION OF BARRIER COATINGS THAT MINIMIZE HYGROSCOPIC CHANGE OF ULTRA-HIGH MODULUS CARBON REINFORCED CYANATE ESTER RESINS

- two of precoatings failed, but others worked
- overcoats to fill pin-holes and for corrosion resistance
- near zero moisture uptake tested - out to forty days
- Phase II submitted

Actuators

BLUE LINE ENGINEERING CO - COLORADO SPRINGS, CO - PI:GREG AMES, COTR:John Rakoczy/MSFC

SUPERCONDUCTING NON-CONTACT ACTUATORS

- Modelling and Analysis tools developed
- Analytically verified significant force can be generated across gaps of several millimeters
- Levitation Experimental Apparatus Developed
- Test Segment with actuators and electronics constructed
- Phase II Proposal submitted late

ENERGEN INC - BEDFORD, MA - PI:CHAD H. JOSHI - Rakoczy/MSFC

LIGHTWEIGHT, LOW POWER ACTUATORS FOR SPACE-BORNE ADAPTIVE OPTICS SYSTEMS

- Developed new Material Recipe
- Designed and constructed an Actuator
- Performed Cryo Tests
- Results as Expected - Phase II Proposal Submitted

XINETICS INC. - LITTLETON, MA - PI:MARK A. EALEY - Redmon/MSFC

MSFC LOW TEMPERATURE DEFORMABLE MIRROR TECHNOLOGY

- performed trader studies
- Developed new Material Recipe
- Designed and constructed an Actuator
- Performed Cryo Tests
- Phase II Submitted

Cryo DM

Metrology

BAUER ASSOC. INC. - WELLESLEY, MA - PI:PAUL GLENN, COTR:Timo Saha/GSFC

MULTI-POINT IN -SITU PROFILING OF LARGE ASPHERICS

- Concept developed.
- Mechanisms Designed.
- Reconstruction Algorithm Derived & tolerances estimated.
- Phase II Proposal Submitted

Cost Analysis

OPTICAL RESEARCH ASSOC. INC - FRAMINGHAM, MA - PI:MARK A. KAHAN, COTR:?/GSFC

OPTICAL ENGINEERING AND COST MODELING SOFTWARE

Milestones - Mirror Materials

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			FY97	FY98				FY99				FY00				FY01
			4	1	2	3	4	1	2	3	4	1	2	3	4	1
Glass	Glass	UoAriz.	PDR	CDR				Ambient Test		Cryo Test						
	Glass/Composite	COI	PDR	CDR				Ambient Test		Cryo Test						
	Gas Bearing Blocking Body	MSFC/Speedring	Start	Delivery		Figure/ Test										
Si Metals	Beryllium	TBD		Start	PDR	CDR				Ambient Test						
	Nickel	MSFC	50 cm Mirrors		Test Ambient Cryo				1 m Mirror		Test Ambient Cryo					
Si	Single Crystal	Schafer	Braze Experiments		Foam Experiments		50 cm Mirrors			Ambient Test						
SiC	CVD	Morton AM	15 cm Mirrors					Ambient Test		Cryo Test						
	Reaction Bonded	Xinetics	Phase II Award(?)									Phase II Award(?)				
	Carbon Fiber Reinforced	SSG	Phase II Award(?)									Phase II Award(?)				
		BDM/IABG	Concept Mirrors		(3) 50cm Mirrors											
	CFR Figure/Polish	TBD			Start			Delivery	Test Ambient Cryo							
	Si Clad RB SiC	TBD	Clad/Polish		Test Ambient/IT/Cryo											
Carbon	Graphite Cyanate Ester	COI	Phase II Award(?)									Phase II Award(?)				
	Pyrolyzed Graphite	Ultramet	Phase II Award(?)									Phase II Award(?)				
	Advanced Mirror System Demo											PDR	CDR		Test Ambient Cryo	

Milestones - Mirror Technologies

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			FY97	FY98				FY99				FY00				FY01
			4	1	2	3	4	1	2	3	4	1	2	3	4	1
Environments	Cryo Coupon Tests	COI	Start	Facility Ready	Cryo Tests											
	NMSD Cryo TestBed	MSFC	Estimates		Chamber Mods		50 cm Test			NMSD Tests						AMSD Tests
	Barrier Coatings for Composites	COI	Phase II Award(?)									Phase II Award(?)				
	Micrometeoroid	MSFC				Prel. Analysis		Impact Studies								
	Coating Stress	MSFC	Coating Select	Coupon fab&coat		Test Ambient Cryo										
Actuators	Cryo Actuator RFO	LaRC	RFO		Phase I complete		Phase I I complete									
	Cryo Magnetostrictive	Energen	Phase II Award(?)									Phase II Complete(?)				
	Cryogenic DM	Xinetics	Phase II Award(?)									Phase II Complete(?)				
Metrology	In-Situ Asphere Profilometry	Bauer	Phase II Award(?)									Phase II Complete(?)				
	FEM Shell Theory	UoTenn		Award		Complete										
	Ni Met Mount Components	MSFC	Procure	Set-up												
Other	DCATT Mirrors	ORNL/ UoAriz	Award	blanks	diamond turn	polish	deliver									
	Steering Mirror	LHD		Award			Deliver									
	Optical System Design	UAH		Award		Complete										

SM100397-0850

Electroformed Nickel Mirrors for NGST
Task Description

NGST

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- *Fabricate 0.75 mm thick, half meter diameter Replicated Nickel Mirror*
- *Prototypical mounting arrangement*
  - *GrEp backplane structure,*
  - *Electroformed Nickel flexures,*
  - *actuators*
- *Test*
  - *Replication Quality*
  - *Hysteresis*
  - *Vibro-acoustic*
  - *Cryogenic Figure*

Electroformed Nickel Mirrors for NGST
Status

NGST

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- *Tooling, Power Supplies, Rotator Assembly, Cold Box Operational.*
- *GrEp Backplane Structure Delivered*
- *One mirror fabricated- figure not good.*
- *Metrology Techniques for 1g Testing“*
- *Active Met-Mount” in development*
- *Planning/Infrastructure Design for production of Larger Optics*
- *Electro-joining Techniques*
- *Process Refinement*
- *Alloy Cobalt and/or Iron with Nickel*
- *Organic Additives for greater MYS.*

Electroformed Nickel Mirrors for NGST
Milestone Schedule

NGST

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•Next mirror to be produced by	10/9/97
•Active Mount by	11/97
•Two more mirrors this year	12/97
•Nickel Alloy (Cobalt) Plating trial &	3/98
•organic additive trial by	3/98
•Cryogenic Test Article by	4/98
•Coating	7/98
•Ambient Test	11/98
•Cryogenic Test	5/99

- FIRM FIXED PRICE
- $750 K for FY 1998
- $750 K for FY 1999
- POCs:
  - james.bilbro@msfc.nasa.gov (205) 544-3467
  - larry.hill@msfc.nasa.gov (205) 544-5046

TABLE 5. MILESTONE SCHEDULE

3/15/98	Contract Award
4/16/98	Requirements Review (RR)
5/29/98	Preliminary Design Review (PDR)
7/2/98	Critical Design Review (CDR)
2/16/99	SBMD Demonstration at offeror facility
3/6/99	Documentation delivered
4/10/99	Final Review
5/1/99	Hardware delivered to MSFC
	(or)
3/1/99	First Option exercised
4/10/99	Cryogenic Test Review
5/10/99	Cryogenic Test
7/10/99	Cryogenic Deformation Correction
8/10/99	Cryogenic Test II
9/26/99	Cryogenic Test Results Review
9/30/99	Hardware delivered to MSFC (under OPTION ONE)

Subscale Beryllium Mirror Demonstrator (SBMD)

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Item	Requirement	Goal	Units
Footprint:	Circular w/one flat side (L=D/2)	--	--
Diameter:	--	≥0.5	m
Shape:	Concave Spherical	--	--
**Radius of Curvature:	$20 \pm 0.001/D^2$	--	m
**Figure:	≤lambda/4	--	waves(P-V (@ 633 nm)
**Mid-Spatial Scale Errors (1-10 cm):	≤lambda/10	--	waves(P-V @ 633 nm)
Surface Finish (micro-roughness):	≤30	≤20	Angstroms(RMS)
*Areal Density	≤12	≤7	Kg/m^2

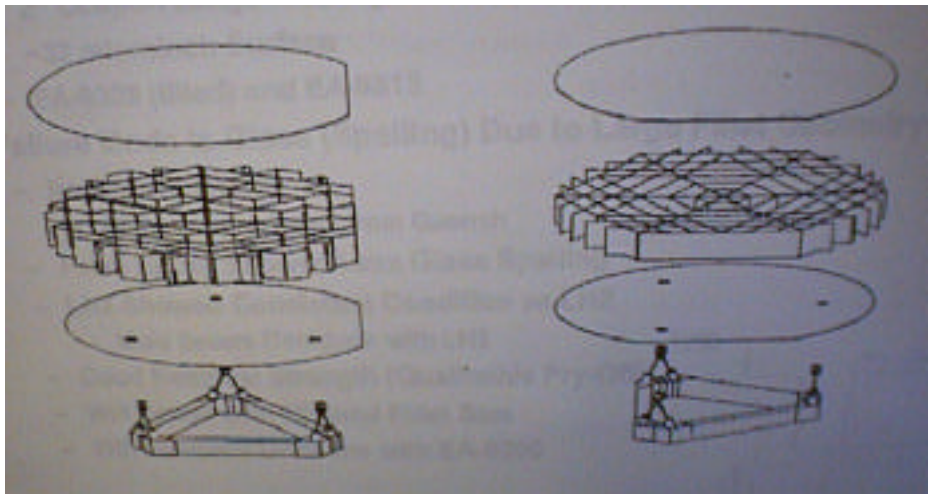
*Includes mirror only. Does not include actuators/flexures, and backplane.

** These requirements can be met by using actuators which must be provided. Additional residual error correction can be performed by a down stream Deformable Mirror (DM). This correction can be shown by analysis and consequently the actual DM need not be included.

D= Mirror Diameter (chosen by the offeror keeping in mind scalability Issues)

Composite Optics, Inc.

- PDR - Oct. 23, 1997 at MSFC
- Material evaluations continuing
  - CTE measurements,
  - effects of moisture barrier,
  - edge bond shear tests,
  - adhesives



- Completing first cut of NGST wavefront error allocations
- Developing manufacturing and test plans
- Core Design Concepts for Mirror Subassembly Options being evaluated
- HDOS to do primary figuring - Kodak possibly to ion figure

University of Arizona

- PDR - Oct 24, 1997 at MSFC
- Continuing efforts to design and optimize glass interface
- performing materials evaluations - predominately CTE measurements
- Developing composite structure designs with COI